Renewable and Sustainable Energy Reviews 38 (2014) 917–932

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Renewable energy project: Project management, challenges and risk

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ARTICLE INFO

Article history:
Received 18 October 2013
Received in revised form
6 May 2014
Accepted 7 July 2014
Available online 26 July 2014

Keywords:
Wind energy
System dynamic
Project management
Planned strategy
Stock-flow diagram

ABSTRACT

Renewable energy is one of the most popular topics in utilization of the electric energy resources. There are various types of alternative energy, which can be used as electrical energy. However, the suitableness of the green energy in a certain country is depending on some criteria such as geographical location, the availability of energy and so on. In order to establish the renewable energy, a well-planned strategy and management must be acquired. The main objective of this paper is to analyse the causal relation of some important criteria of project planning and development of a wind energy project in Malaysia. By using a system dynamic approach, it is found that government policies, investment of renewable energy, energy demand, geographical location and fund management are the most important criteria that need to be considered among others. The diagram of causal relationship with reinforcing and balancing loop shows that the application of renewable energy in Malaysia is promising. In addition, the information of the criteria relationship is further investigated by using the stock flow diagram. From the diagram, the factors that affect project's expenditure could be analysed. This is very important to a developing country where more budgets can be allocated for other facilities, cultures, infrastructure, science, and technology development. By utilise the renewable energy in Malaysia, the carbon dioxide emission can be reduced and contribution to a sustainable and long term alternative energy resources country.

Contents

1. Introduction

Carbon dioxide emission is one of the causes that contributed to the global warming. According to U.S. Energy Information Administration (EIA), the total carbon dioxide emission from the

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http://dx.doi.org/10.1016/j.rser.2014.07.078
1364-0321/

energy consumption in the world is 31,780.36 million metric tons in 2010 [1]. The carbon dioxide emission in China is the most in the world follow by North America and United States. Meanwhile, out of 0.6% of the total carbon dioxide emission is coming from Malaysia. In order to reduce the amount of carbon dioxide emission, the alternative ways in generating electricity must be utilised. For instance, China and United States used renewable energy as a part of electricity generation in the country. From the data of EIA, the total renewable-energy electricity generation for China and United States in 2010 is 770.92 billion kW h (or 770.92 TW h) and 427.38 billion kW h, respectively [1,2]. At the same time, Malaysia which located at the equator has used the renewable energy and generated 7.69 billion kW h or equivalent to 6.5% from entire electricity generation in 2010 [3].

Apparently, the electricity generation produces thousand million metric tons of the carbon dioxide. In order to minimise the impact of carbon dioxide towards global climate change, many countries approached renewable energies as the alternative electricity generation system. There are various types of renewable energies can be used. However, the suitability in terms of the availability of renewable energy in that particular country is the most important criteria. In such circumstances, the feasibility of the renewable energy must be studied before the project can be started.

As the electricity generation by using the coal fire power plant, the carbon dioxide will release due to the burning process and that will contribute to green house effect. Meanwhile, the electricity production by using renewable energy only produces negligible carbon dioxide emission. Carbon dioxide naturally exists during the respiration process of human beings. Plants will absorb the carbon dioxide and release oxygen during photosynthesis. However, with the vast development of technology that contributes to the huge amount of carbon dioxide emission since last decades, the intensity of carbon dioxide in atmosphere increased and caused green house effect. In order to reduce the amount of carbon dioxide in atmosphere, many countries have the awareness on using green energy that only released small amount of green house gas.

Wind power is one of the lowest carbon dioxide emissions in between the renewable energies [4]. The zero carbon dioxide emission from the wind power has been encouraging the power service provider on selecting it for the electric power generation.

Fig. 1. The wind ranking of Malaysia by using Firstlook.
Source: Author's construction based on ⟨http://www.3tier.com/en/⟩.

Fig. 2. Sabah grid interconnection map.
Source: Author's construction based on ⟨www.thegreenmechanics.com⟩.

As the largest carbon dioxide emission country, China has installed the most wind power which is 75.56 GW up to end of the year, 2012. United States used 60 GW of wind power to be converted into electricity and follow by Germany [5]. Meanwhile, Malaysia installed a 75 kW hybrid integrated renewable energy, wind–solar power plant in Perhentian Island [6]. The main electricity consumers are the villagers and tourists around the island. In order to use the wind energy as it can be connected to the main power grid, a larger wind farm is required.

According to the online wind power analysis software FirstLook, the wind speed in Kudat, Malaysia is promising if compared with other locations [7]. Fig. 1 shows the indication wind speed in Malaysia by using Firstlook. The wind farm project is feasible for the particular place in east peninsular Malaysia. As for this research, wind farm is planned to install at the wind promising area and interconnect to the grid of Sabah, which operates by Sabah Electricity Sdn. Bhd. (SESB). For long term consideration, it can be an extra electricity resource to be sold to Sarawak or even Peninsular Malaysia by using the power corridor. The proposed area is near to main grid line in Sabah as shown in Fig. 2. In order to run the project, there are many criteria need to be considered. The project criteria might cover the feasibility of the wind power in Malaysia, the availability of the maintenance skills on wind turbines, the stability of the power generation, the financial, policy, and technical risks, as well as the project team to ensure no delay and finish on time.

The well organised planning is the key of success for a project. The predictable wind speed is a decision factor that could encourage the commencement of a wind power project [8]. Due to this, the wind farm site has to be highly accessible by the wind. The assumption economic return must be clarified in order to persuade the investors on spending the money in the project. Nevertheless, the wind speed data can be obtained from the meteorology department; the actual site condition should be studied for a better assessment of a project. For planning purpose, the obtained data can be modified according to a different height of the tower hub by using the mathematical formula.

On top of that, the risks of the project must be analysed in order to minimise the loss of revenue. Economic risk and the technical risk play destructive roles in building up the project [9,10]. The initial cost of running a project might be high. A 900 kW wind turbine manufactured by Wind Inc. cost 1.5 million USD [11]. Hence, a strong financial management is necessary. On the other hand, the technical skills play an important role during the wind-turbine installation and after sales services. Even though many of the manufactures claim that wind turbine can be at least last for 20 years; sometimes the faults like the sensor problems, gearbox problem or even control system problem can be happened due to wear and tear condition [12]. With a strong technical background, the investment allocated in the project would not waste in vain. By using the system dynamics analysis method, the relationship in between the criteria can easily be seen and analysed. The method of analysis will be discussed in methodology.

2. Literature review

As mentioned earlier, the fund management of the wind-power project plays an important role of the key factor that might affect the progress of a project. Yunna used structural interpretation method (ISM) to analyse the major factors that affected the implementation of effective cost control [13]. The factors such as the cost competition in between the manufacturers, project contractors, adaptability of wind turbine to the market, and the implementation responsible costs are the main cause of price variation [13].

In order to maintain the stability of the electrical system, the generated power should be more than the demand. Hence, a well-planned location of the renewable-energy plant deployment could affect the effectiveness of the electric power transmission system. For instance, the wind farm with the higher wind access should be able to cover the lower wind density site. Therefore, the average power generated would not drop and not affect the power quality of the system [14]. In order to achieve better operating benefits, a high wind speed and a good wind regime in a site are the factors to a successful wind farm investment [15].

Policies, rules and regulations are the factors that either boost up or slow down a wind-power project. As looking into the two forerunners of the wind-power project, United States and Germany, Germany possessed a better preparation in providing the low carbon green energy [16]. Although Malaysia is not emphasizing in the wind-power project, the policy of government still encouraging investor to increase the renewable-energy contribution to the national grid as well as create a sustainable living environment [17].

Besides that, the management of the landscape for the wind farm might increase the acceptance of public. The occupied land or sea area might have other interests from government or even military. The survey of the interest from other parties should be done as early as possible. Michler and Krause figured out that wind farm–marine culture activities might be suitable for the offshore wind farm project [18]. In such circumstance, government supports and the negotiation with the fishery or agriculture sector could realise the combination of multiple activities in a wind farm.

In addition, the maintenance skills of technicians and knowledge of engineers in analysing the faults and solve the operation problems are very important for after sales services. The wind turbine might breakdown due to the sensor fault, the gearbox problem, and all the wear and tear problems. The solution must be correct and effective in order to minimise the break down time and increase the productivity of the wind farm [19].

In Malaysia's scenario, there were researchers conducted wind power assessment at Kudat and Labuan by using Weibull distribution function [20,21]. The assessment was done by analyzing wind speed data of the targeted area. From the results of research, Kudat is preferable than Labuan for wind power plant establishment [20]. In terms of wind speed analysis, another group of researchers also conducted wind direction detection by using von Mises mixture distributions [22]. The potential site that undergoes wind speed and direction study is located at Mersing. Besides, hybrid renewable energy building is also one of the topics that being discussed by the researchers [23]. Optimization of energy resources usage among solar power, wind power, and diesel generator was introduced in the paper. The production cost for each kW h of electricity is rated 0.17 USD. Besides, a research regarding the selection of renewable energy by using Analytical Hierarchy Process (AHP) has been done and wind power is considered as more environmental friendly compared with other criteria [24]. In order to reduce the carbon emission, Malaysia's government has launched National Renewable Energy Policy in 2010 after failure of renewable energy policy execution in 2002 [25]. In fact, Malaysia's government has allocated RM19 billion of loan for the renewable energy project [25,26] in conjunction with the launched policy.

3. Methodology

In this study, system dynamics is being used in the analysis of project management of wind turbine. Although Malaysia is still new to wind power project, the analysis will base on the environment, government's policies, and site condition in

Malaysia. System dynamic is developed by Jay Forrester in the year 1961. With the aids of computer simulation, the overall system behaviour can be analysed. By using the casual loop diagram (CLD), the relationship in between the variables or parameters can be identified. Many researchers applied system dynamics in a different field of studies. Erma, Shuo, and Chen apply system dynamics to analyse the air passenger demand in the airport [27]. The inter relationship of the criteria is clearly to be seen, and a flow diagram can easily explain the complicated system. Erik, Ann and Kim study the service quality of restaurants that affect the capital allocation [28]. By using CLD, it explains the gains and losses that might be encountered by the company due to the expansion of capital or gaining the popularity. The applications of system dynamics vary from decision making, software development, strategic planning, or even project management [29–36]. For this paper, the system dynamics applied in the wind power project management. The relationship in between the government policies, the fund allocation for renewable-energy project, energy demand, environmental impacts, geographical location and maintenance skills will be studied. Fig. 3 shows the basic CLD of the power generation, energy demand, and number of wind turbines (resources) by using the simulation tool, VENSIM. In Fig. 3, the number of wind turbines can affect the total power generation. The polarity at the end of the arrow means that by raising the number of wind turbines can increase the power generation. This loop is called reinforcing loop and represents as "R" in Fig. 3. Meanwhile, "B" means balancing loop where the energy demand (consumption) will equal the power generated.

In order to study the revenue and the return of investment (ROI), the power production in a year is obtained by using recorded wind speed from Meteorology Department Malaysia. The wind speed for the potential wind power site, Kudat is tabulated as in Table 1.

According to Betz's Law, the maximum power that can be extracted from the wind is 59.3% out of the undisturbed wind. The power can be converted into electricity is calculated by using Eq. (1).

$$P = \rho A v^3 c_p \quad (\mathrm{W}) \tag{1}$$

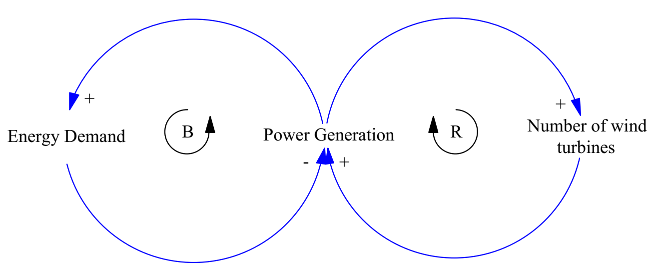

Fig. 3. The causal loop diagram (CLD) of the power generation, energy demand and number of wind turbines.
Source: Author's construction based on VENSIM software.

Table 1
Monthly mean wind speed in Kudat Malaysia from 2002 to 2010.

Month year	Jan	Feb	Mac	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2002	9.6	7.1	5.7	4.1	2.5	3.0	5.0	5.7	3.6	3.4	2.7	6.1
2003	8.0	9.1	6.6	4.5	4.1	3.0	4.8	4.3	5.5	5.7	3.4	7.7
2004	9.6	6.4	4.8	4.3	4.3	6.6	4.1	5.9	2.7	5.9	3.0	4.1
2005	4.3	5.5	4.8	5.7	4.8	4.5	5.5	5.5	5.7	5.2	5.5	3.6
2006	5.9	7.7	5.2	5.0	4.8	4.8	4.8	5.9	5.2	6.1	4.8	5.2
2007	5.7	7.1	5.9	5.2	4.3	4.5	5.2	5.0	6.4	5.0	6.6	4.8
2008	5.7	5.9	4.8	4.5	5.7	4.3	5.0	4.1	5.7	4.3	4.1	4.5
2009	5.9	5.5	4.8	5.9	5.0	5.0	5.7	6.8	7.3	6.4	4.8	6.6
2010	7.1	7.7	6.8	5.7	5.0	4.5	4.3	5.5	4.5	5.5	4.3	4.5

where P denotes the power captured by the wind turbine; A indicates the swept area of the rotor; v^3 is the cube power of the undisturbed wind speed; c_p is the ideal power coefficient of Betz's Limit, 16/27.

In this case, the Vestas wind turbine, V112-3MW is chosen to obtain the wind turbine parameters in order to suit in the formula. For Vestas 112-3MW, it has a rotor diameter of 112 m and the hub height of 119 m [37]. The swept area of the wind turbine is calculated by using Eq. (2).

$$A = \pi \ r^2 \ (\mathrm{m}^2) \tag{2}$$

where $\pi = 3.142$; r represents the radius of the wind turbine rotor.

The efficiency of the wind turbine is assumed to 90%. The wind turbine cannot achieve 100% of efficiency in reality. This is due to there are some losses during the energy conversion process. The mechanical power will be converted into electrical power through the generator. The total power that can be converted into electrical energy is calculated and analysed in next session.

3.1. System dynamic modelling

In general, the wind power project can be divided into three major assessments. First assessment will be the preparation for the project, or so called budgetary. The financial support such as loan from local banks could be initiated by using the budget computed. Second assessment will be the technology progress. The supervision of the authorities on the construction progress is the main part of this assessment. This cycle might determine the cost of construction. A construction project which undergoes smooth progress as per expectation could save a lot of unnecessary expenses such as overtime labour. Besides, the delayed of the project would delay the service of the wind turbine that caused the losses in revenue. Last but not least, the maintenance of the wind turbine and the sustainable energy assessment which contributed to the expenses within the wind turbine lifetime. The maintenance is necessary to prevent the malfunction of the wind turbine. Normally, the maintenance contract will be proposed by the manufacturer after the warranty period ended. These parts are combined as complete system analysis.

3.1.1. Electricity demand sub-model

In the first assessment, the wind resource's availability is the critical element. The wind resource's assessment could be done on-site or prediction. Wind speed is the energy resource for the wind turbine. The wind speed could determine the electric power generated by the wind turbine. As for this research, the prediction of the wind speed was done in order to predict the possible wind speed in the particular site. The wind speed in the future can also be predicted by using the proposed methods. As the wind speed increased, the energy that could be harnessed will also increase. The interests of both elements are in the same way. Therefore, the symbol "S" is shown in Fig. 4. The factors that affect the electricity generation are also listed in the causal loop diagram (CLD). For the demand of electricity, it could be affected by two factors in general. There are population and the gross domestic product (GDP) growth. As the numbers of the consumer increase, the electricity supplies to each household also increase. This indicates the same interest in between population and the demand. It is assumed that the GDP growth might excite the growth of various sectors such as the service sector, manufacturing sector, and so on. In the development of a country, electricity is the major element that could not be neglected. For instance, the Petronas twin tower consumes average 62 million kW h or equivalent to 62 GW h annually from 2009 to 2011 [38]. The more advance of a country, the more electricity demand of the country. Thus, the GDP is directly proportional to the demand of electricity.

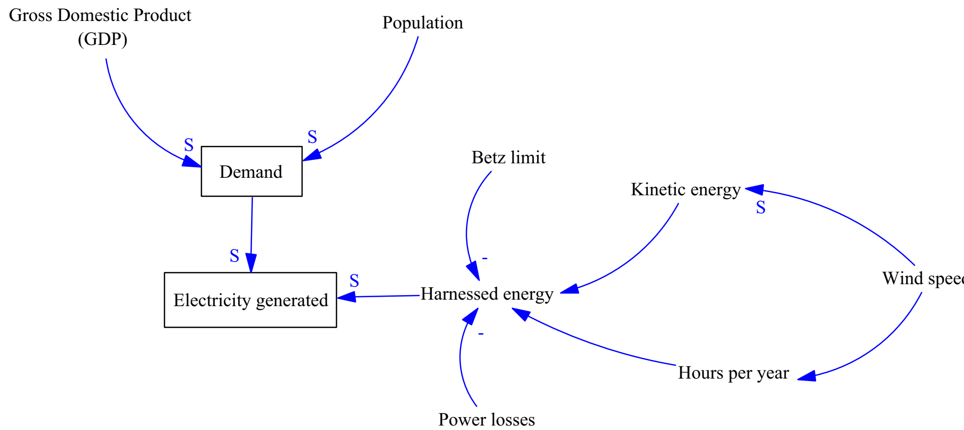

Fig. 4. The causal loop diagram for the relationship among demand and electricity generated.
Source: Author's construction based on VENSIM software.

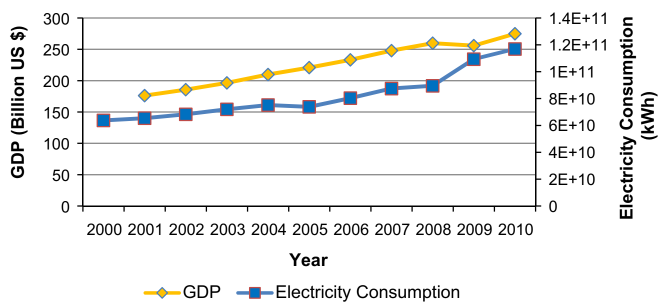

Fig. 5. The graph of GDP growth and electricity consumption in Malaysia from 2001 to 2011.

There are a lot of related works regarding the relationship in between gross domestic product (GDP) and electricity demand was done by researchers. For instance, the economic report done by Frontier [39] was clearly stated that the GDP growth to the electricity volume growth is the one-to-one ratio. This meant that for every increase in the GDP, the electricity consumption will also increase. The particular research included the residential and non-residential sectors. Several assessments on the relationship of GDP and electricity volume were done by the financial group. There were several groups of the researchers had worked on this context since decades. Mahadevan and Asafu-Adjaye stated that the growth of electricity consumption is directly proportional to the growth of GDP [40]. In the paper, the authors stated that developed countries might have a smaller increase of the electricity consumption for every increment of percentage in GDP. This is because the technology available and the efficient energy management could control the trend.

In the research done by Narayan and Smyth [41], they found out the price of the electricity and hot surrounding temperatures are the causes that might change electricity demand. They only focused on the residential electricity usages. They also stated that every 1% increment of the GDP would lead to 0.41% increase in electricity consumption for long term. This is because the residential would take some time to overcome the variation of the GDP that brings the changes to their lives. This phenomenon is also known as lagged electricity volume.

For Malaysia, the relationship in between growth of GDP and increment of electricity demand can be investigated by using data provided by the World Bank [42]. A series of economic data was downloaded from the online database. The data of electricity consumption in Malaysia from year 2001 to 2011 was obtained and plotted as in Fig. 5.

Despite the theory of the one-to-one ratio for the GDP growth rate and electricity consumption relationship, the real data for the corresponding elements for Malaysia are tabulated as in Table 2 and plotted in Fig. 6. From the observation of Table 2, it is obvious that the electricity consumption is increased corresponds to the GDP growth. The average GDP growth in Malaysia throughout nine years is 4.6% whereas the average increment of electricity consumption is 6.6%. The average ratio of every GDP growth to the electricity consumption is 1:1.4. Therefore, this ratio will be used as the factor in this relationship for the system dynamics analysis.

Besides the electricity demand, the resource availability plays an important role to ensure the electricity supplied by the wind turbine is always sufficient. Although the wind energy is free, the duration of wind blow is uncontrollable. Therefore, a wind power system is normally equipped with a backup system. It might be either energy storage for the wind power or a diesel generator to boost up the electricity supplied. However, the backup system is not in the scope of this research and is excluded from analysis. This research only focused on wind power prediction for the targeted site.

3.1.2. Technology process sub-model

The progress of the wind power project includes the financial planning of the project, the project management, government submissions, and construction progress. A strong financial support is always the motivation of a project. However, a project could not succeed without a good management. Therefore, an early planning on a project could minimise the unnecessary incidents to happen.

In order to build up a 1 MW wind power plant, an estimation of US $ 1.8 million or equivalent to RM 5.4 million of capital is required [12]. In terms of financial analysis in system dynamics, another assumption is made on the 90% of the total investment would be financed through local banks. The interest rate is adjustable in the system dynamics analysis in order to investigate the possible impacts that might bring to the project development. From the data provided by World Bank, the interest rate in Malaysia from 2001 to 2010 is fluctuating in between 2.5% and 3.75% and achieves 1.805% in 2012. The consequence of the increment in an interest rate is significant for the huge amount of lending. Therefore, a developed country normally provides lower interest rate for the investors to excite the market in the country. In Germany and Denmark, the commercial banks provide lower interest rate to the wind turbine projects. This act could encourage the development of renewable energy in the country.

Besides, the submission of the documents to the local authorities could affect the overall construction time. A wind power

Table 2
The relationship of GDP growth rate and electricity consumption growth rate in Malaysia from 2002 to 2010.

Year	2002	2003	2004	2005	2006	2007	2008	2009	2010
Electric power consumption (TW h)	68.3	72.0	75.2	73.8	80.3	87.5	89.5	109.0	117.0
Electric power growth rate (%)	**4.4**	**5.4**	**4.4**	**−1.8**	**8.8**	**8.9**	**2.3**	**22.2**	**7.0**
GDP growth rate (%)	5.4	5.8	6.8	5.3	5.6	6.3	4.8	−1.5	7.4

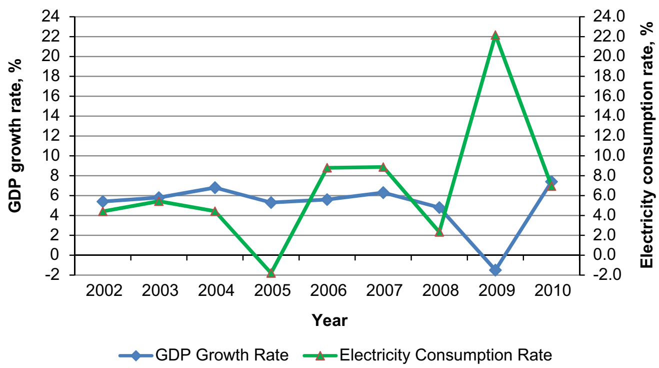

Fig. 6. The graph of GDP growth rate and electricity consumption rate in Malaysia from 2002 to 2010.

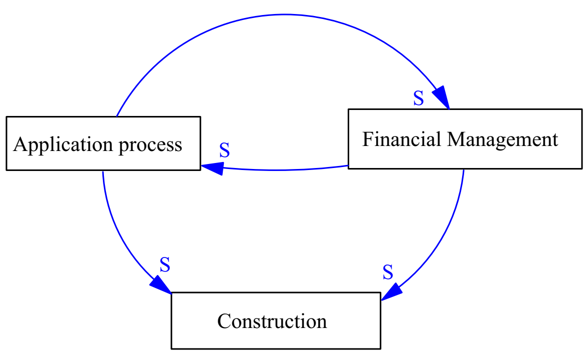

Fig. 7. Causal loop diagram for the technology process assessments.
Source: Author's construction based on VENSIM software.

farm requires a large land area to establish the wind turbines. The land could be requested from the landlord or government. It could be a long term rental from the authorities or by purchase, the land for hassle free. In addition, there are a lot of assessments such as a load test on the construction site, approval from local engineering consultancy firm, financial contract, and procurements needed to be done before the construction of the project to commence. This could take one or two years to complete these paper works and assessments. The longer time it takes, the longer construction time will be. This shows the same interest in the relationship between application process and construction.

The initial draft of the CLD for the second assessment is shown in Fig. 7. The CLD is derived from the assumptions and hypothesis made from assessments. A stronger financial fundamental could lead to better project development. This shows the same interest of the financial management and construction. Another hypothesis is made: a project could be commenced in shorter time as the applications and the paper works could approve earlier. There are a lot of parameters and elements involve in this process. The details in the relationship among each others will be presented in results and analysis section.

3.1.3. Maintenance sub-model

This assessment is more on after sales service. Once the wind turbines are established, power plant will start to operate to

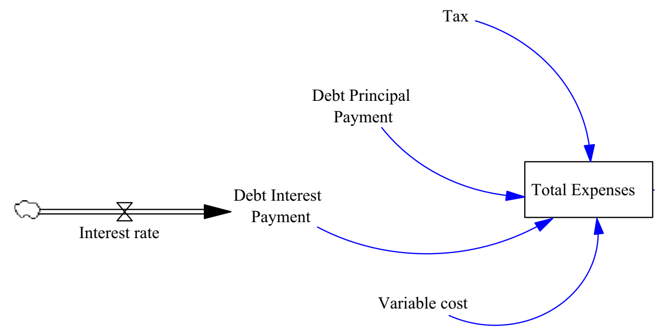

Fig. 8. A basic CLD for total expenses for a wind power project.
Source: Author's construction based on VENSIM software.

supply the electricity to consumers. The income is generated from selling electricity. For every investment of a project, the return of investment (ROI) is very important to the investors. It is the time when the capital is being paid. The breakeven point would determine the possible net income that earned by the electricity generation. However, the constant repayment to the banker who comprising interest and repayment also known as annuity is required to determine the period of ROI. The annual principal payment to the banker can be expressed as in Eq. (3).

$$P = \frac{P_V \times R}{[1-(1+R)^{(-n)}]} \tag{3}$$

where P denotes the annual payment of the loan; P_V denotes the total loan; R denotes the annual interest rate (decimal); n denotes the debt term (year).

A payback period or ROI is determined when the initial capital investment is fully recovered and achieved a positive cumulative cash flow. For this research, the initial capital for the investment is assumed to be 10% of the total cost of construction. A positive cumulative cash flow is achieved when there is a positive value after deduction from the total expenses and total revenue. The Eq. (4) expressed the calculation for the net cash flow.

$$C = P_I + C_R - E_T \tag{4}$$

where C represents the cumulative net cash flow; P_I denotes the initial capital for investment; C_R denotes the total revenue from electricity generation; E_T denotes the total expenses.

Fig. 8 shows a CLD for the total expenses for a wind power project for the cumulative net cash flow. There are four possible factors that contribute to the total expenses for a running wind power project. Those are taxes, debt principal payment, debt interest payment, and variable costs. In Malaysia, the pioneer status of the renewable energy developer could enjoy 100% of tax exemption for 10 years [43]. For the existing corporate, the tax exemption is up to five years. Developers also given the indirect tax exemption such as duty free for the equipments related to renewable energy generation. This could gradually reduce the burden of the green energy developers and encourage pioneers to contribute in green energy development.

According to the Green Technology Financial Scheme 2010 (GTFS), Malaysia's government will bear 2% from the interest over profit rate [44]. In addition, government also guaranteed 60% of

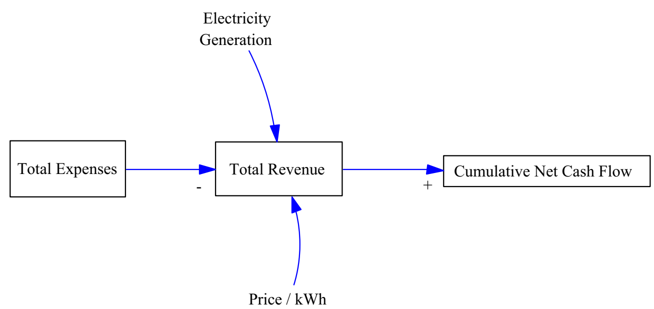

Fig. 9. The overview of CLD for calculating the cumulative net cash flow for a wind power project.
Source: Author's construction based on VENSIM software.

the financing approved amount. Each company can also apply financing support for maximum RM 50 million and total government's funding is about RM 1.5 billion. The actual debt interest is relying on the interest rate of the year. All these parameters will be taken into account for the analysis of the total expenses.

The variable cost is the unexpected cost for the maintenance and therefore is considered into an analysis model to cover the expenses. Generally, a wind turbine provider will come with a warranty. Once the warranty period is over, a maintenance contract could be introduced. The variable cost may cover those wear and tear parts such as lubricant.

Another element for the cash flow analysis is the total revenue obtained within the wind turbine lifetime. Technically, wind turbine manufacturers claim that a wind turbine can operate up to 25 years. Thus, the total revenue and the total debt should not exceed this value for the analysis. Fig. 9 shows a CLD of the total expenses, total revenue and cumulative net cash flow for a wind turbine in a wind power project.

4. Results and analysis

The main criteria that encourage the wind-power project can be categorised into four. One of the criteria is the government policies. Normally, a certain policy could be revised into few revisions based on demand in that particular period. These revisions may include the risk analysis, economic analysis, feasibility of the policy, and the feedbacks from publics. The policy such as giving the incentives, tax exemption or a low-interest loan will encourage the development of a massive project. In this paper, wind power project is focused. A wind power project needs a large amount of funds and normally takes 3 to 4 years from a site visit until signing of contract. The wind power generation is directly proportional to the number of wind power project installed. However, the increase of the number of wind power project should depend on the effectiveness of the first project. Hence, it is very important to organise and supervise the new project carefully.

With the installation of the wind power in Malaysia, there is more variety on the power generation system. As every kW h of electricity sells to the consumers, there will be revenue. The revenue will be used as either the maintenance of the existing power generation system or fund raising for the next project. If the power generated from wind power is promising, the government policies will tend to build more wind farms. The relation in between the main criteria can be illustrated in Fig. 10.

4.1. First assessment

The assessments of the wind power project in Malaysia are analysed in different phase in the system dynamic analysis. The final structure of the overall system will be presented after analysis for each phase had done. Basically, the system dynamics modelling can analyse by using software that available in the market. For the educational research purpose, Ventana Systems provides freeware to the researchers [45]. Vensim PLE is system dynamics analysis tools that can analyse the system relationship by self compute an inter relation formula.

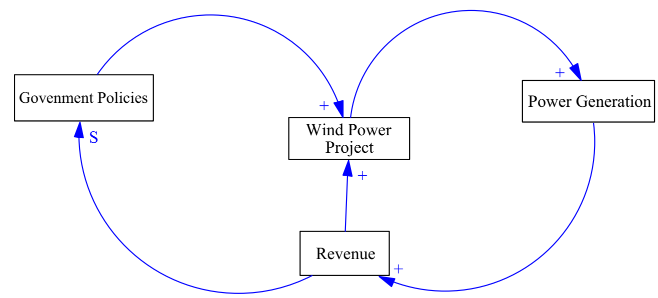

Fig. 10. The CLD of main criteria that affect wind power project.
Source: Author's construction based on VENSIM software.

For the first assessment of the wind power project, the electric power that could be generated from a wind turbine is analysed. There are three parameters that affect the power density; they are air density, wind speed and swept area, respectively. Each parameter is acting in the same direction of interest with the power density. Apparently, for every increment or decrement of the parameters could affect the power density in the wind. However, a wind turbine has an energy captured limit which called Betz' limit as presented. Ideally, the Betz' limit is 0.593 for a wind turbine. Therefore, the maximum wind energy which can be harnessed by a wind turbine is further reduced by a fraction of 0.593. There are power losses during the energy conversion from mechanical energy to electrical energy. Besides, the technical availability could affect the operation time of a wind turbine. This is an important issue that every wind turbine operator concerned. For every non-availability that caused by several reasons might bring losses to the energy provider. There are some important factors which are not counted as the non-availability of a wind turbine. Those factors are listed as follows [12]:

i) Recovery times for routine maintenance.
ii) Standstill times due to intervention by operator or third party.
iii) Standstill times due to grid outage, lightning strike, ice accumulation.
iv) Standstill times for whatever reason for less than 5 h a year.

According to Faulstitch et al., the availability for the onshore wind turbine can achieve 98% [46]. There is only 5% from the downtime of wind turbine is caused by the product failure. This figure shows that the wind turbine is becoming more reliable and can compete with other power generating plants.

The simulation on the change button in the Vensim analysis tool enables a user to analyse the system response towards the possible changes. Fig. 11 shows the simulation of the electricity generation from a wind turbine. The swept area of Vestas 3.3 MW wind turbine is 12,469 m^2. In Fig. 11, the "Electricity generated from a wind turbine" is in a box type. The box type variable can simulate the cumulative values of a series of data based on the equation input in the Vensim. The maximum analysis period is set to 25 years. This is because most of the wind turbines are technically stated with a lifetime of 20 to 30 years. Therefore, an average of 25 years is expected for the Vestas 3 MW to generate the electricity.

In the context of the relationship of GDP growth rate and the electricity consumption, the flow diagram is built and shown in Fig. 12. The initial GDP is set to US $255.88 billion which is the GDP value in 2009. There was an increment of 7.4% or equivalent to US

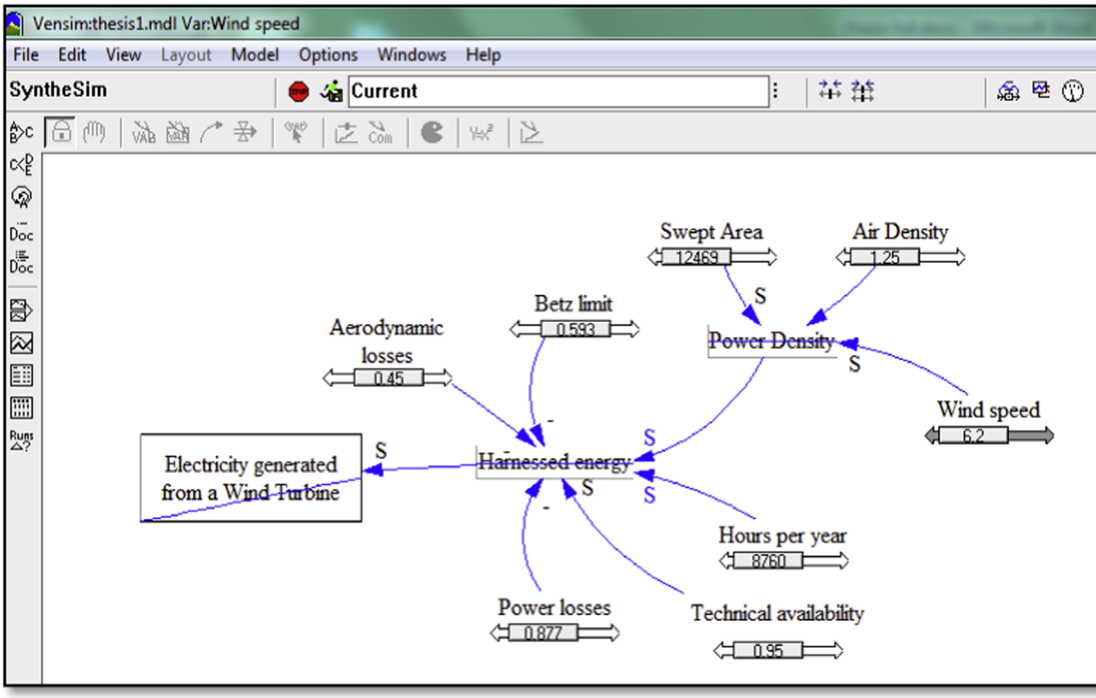

Fig. 11. Simulation on change for the electricity generation flow diagram.
Source: Author's construction based on VENSIM software.

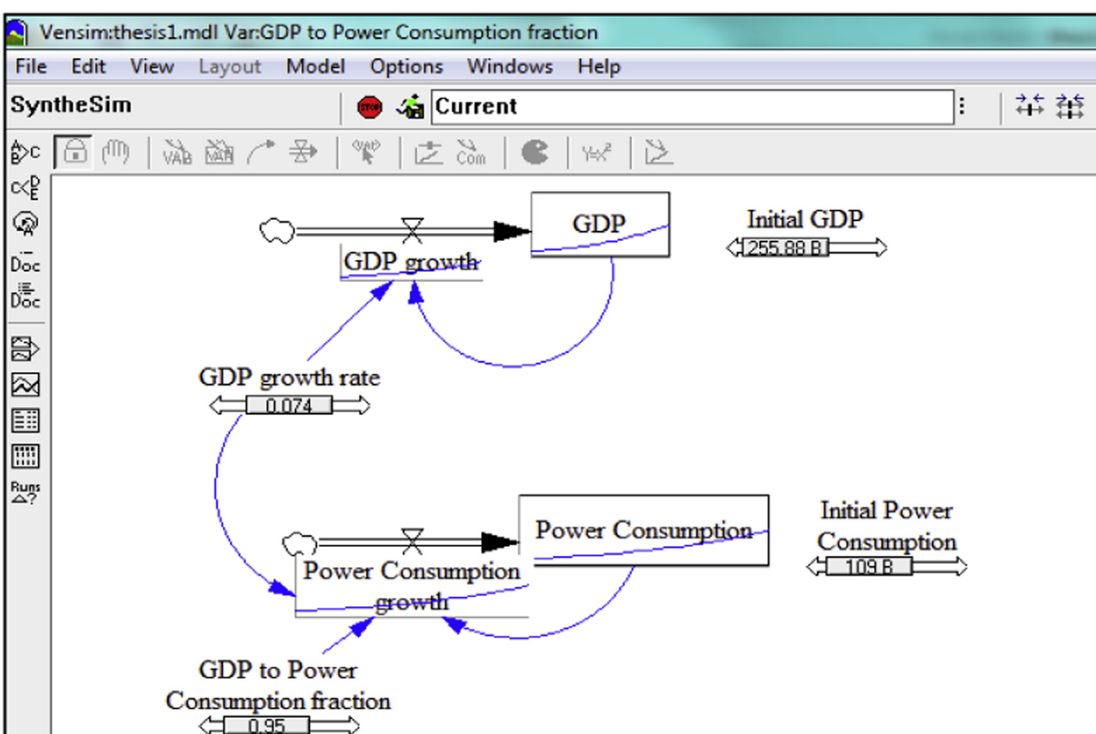

Fig. 12. The flow diagram of electricity demand corresponds to GDP growth rate.
Source: Author's construction based on VENSIM software.

$ 274.811 for the GDP in 2010. The result of the GDP analysis is shown in Fig. 13. Meanwhile, the recorded power consumption in 2009 is 109TWh. In the transition of 2009 to 2010, the ratio of GDP growth to electricity consumption is 0.95. Therefore, the GDP to power consumption fraction in the flow diagram was set to that value. The result of the power consumption is illustrated in Fig. 14.

4.2. Second assessment

For the second assessment of the wind power project by using system dynamics analysis, the application process, construction time and the financial management are involved. A normal process of a wind turbine construction is from six to twelve months.

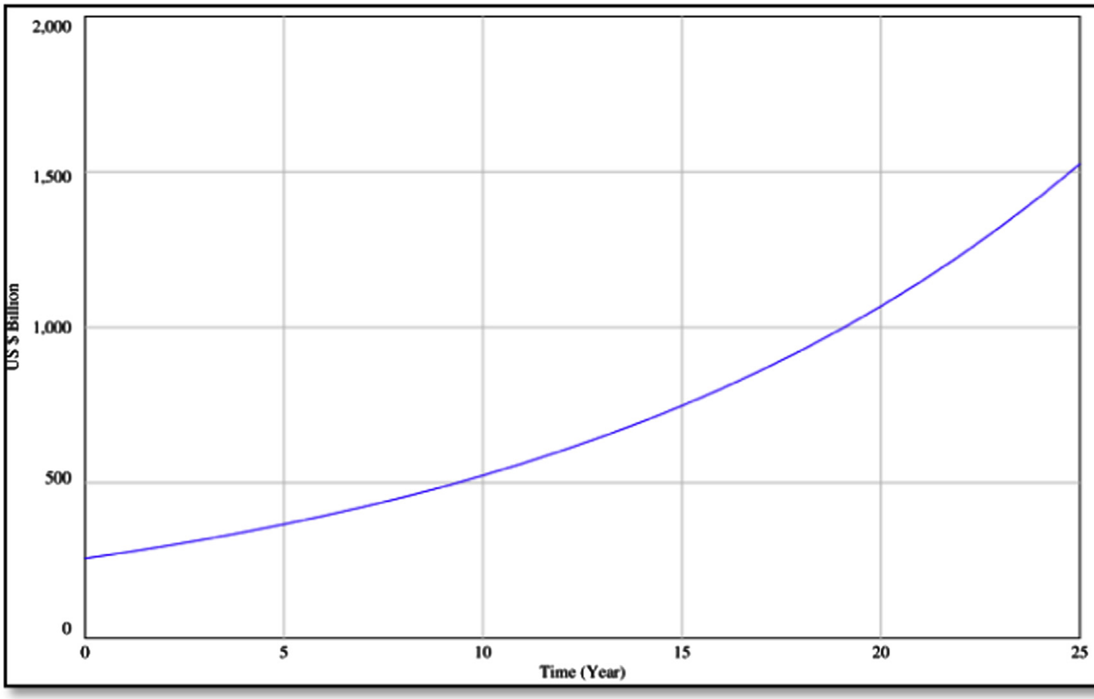

Fig. 13. The expected cumulative GDP over 25 years.
Source: Author's construction based on VENSIM software.

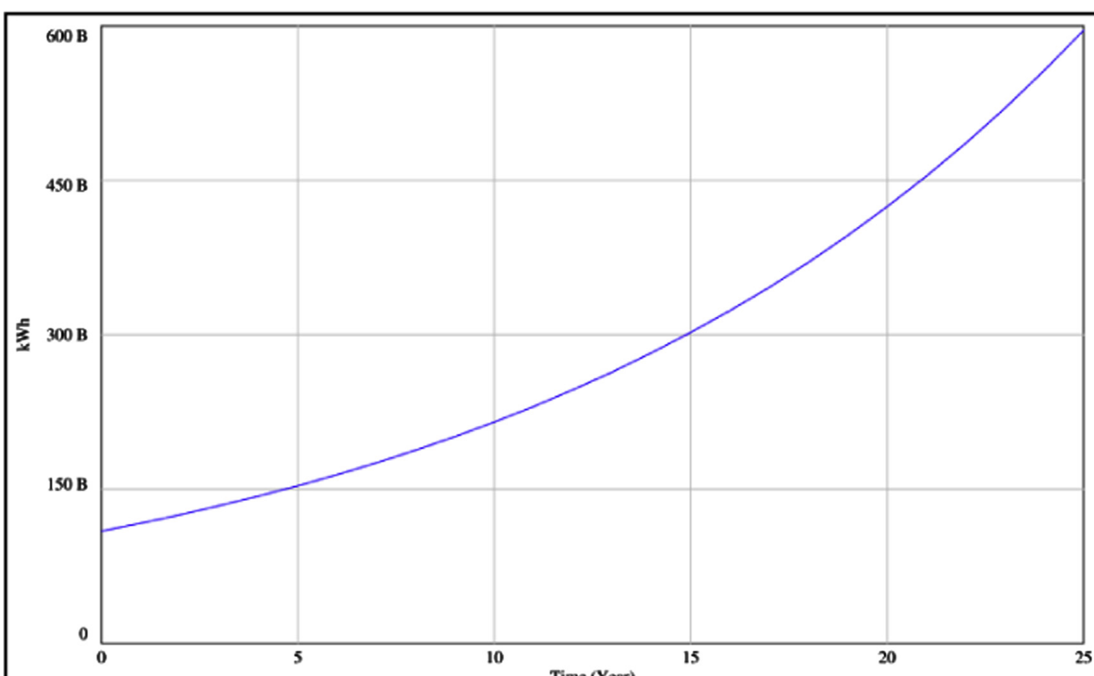

Fig. 14. Power consumption growth corresponds to GDP growth over 25 years.
Source: Author's construction based on VENSIM software.

However, from the first site inspection till the project completion could take up to three years. For this research, the relationship of the delay factor inclusive the documents' processing time to the construction time and construction cost is investigated. The flow diagram as shown in Fig. 15, the delay factor is set to one which means no delay occurred. The smaller fraction of delay time indicates a faster processing time or vice versa. Besides, the construction cost is highly related to the number of wind turbine to be installed in a wind farm. Theoretically, the construction cost for the proposed wind turbine is estimated US $ 5.4 million or equivalent to RM 16.2 million for one unit. It is expected to have at least three wind turbines for the proposed site.

4.3. Third assessment

This section is mainly about the after construction analysis of a wind power project. The most important part of the project is the potential ROI. In order to compute ROI of the proposed project,

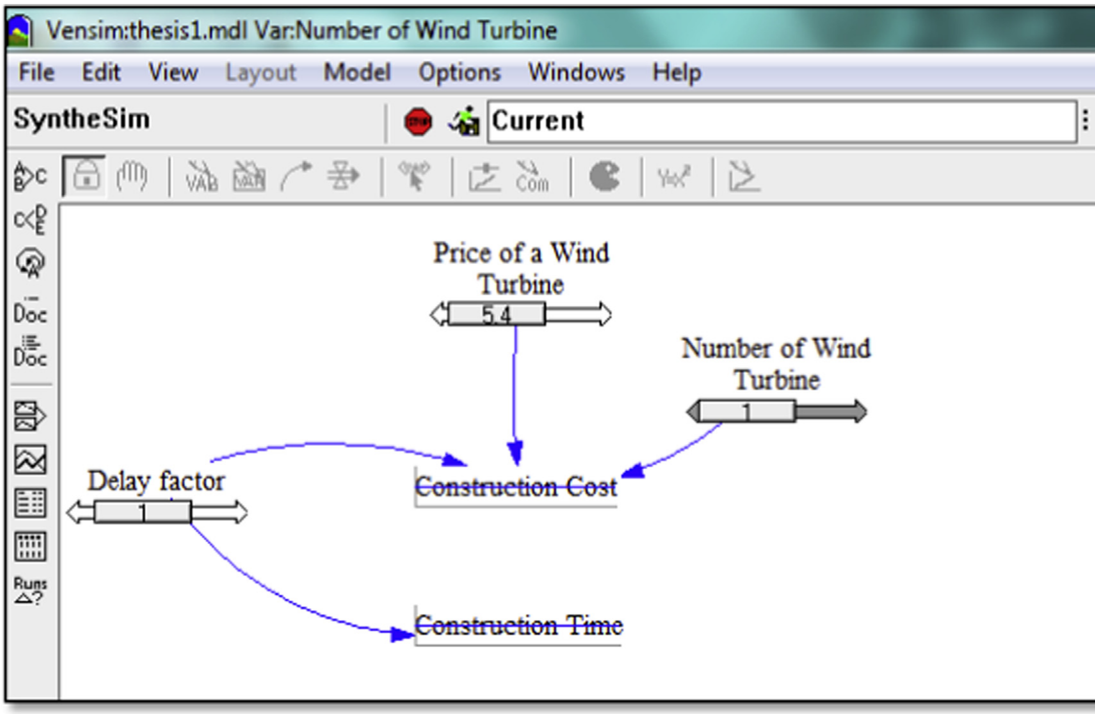

Fig. 15. Flow diagram of the construction cost and construction time with respect to delay factor.
Source: Author's construction based on VENSIM software.

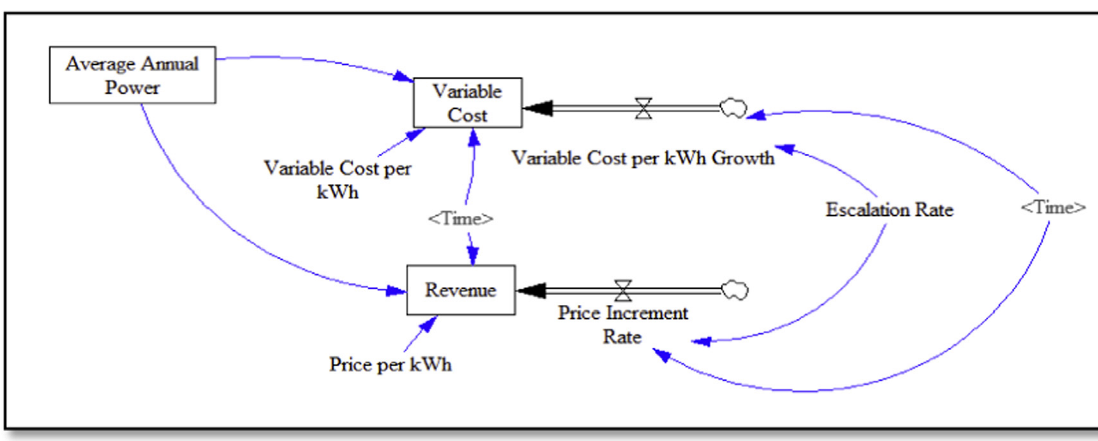

Fig. 16. Flow diagram for the revenue of a wind turbine.
Source: Author's construction based on VENSIM software.

a series of analysis should be done beforehand. Each element and parameter are closely related to each other's. The power generation from the first assessment, the annual wind power generation and the energy demand are playing important roles for a complete analysis. From the previous analysis, the average annual power has obtained. The revenue of a wind farm can be calculated once the wind turbines are operating. Generally, for every kW h of electric power generated to multiply with unit price results in revenue. Most of the power service providers shall increase the electricity price once in awhile to overcome the generation cost and inflation. For this reason, the escalation rate is considered in the analysis. It is expected to have a 2% of the increment in the escalation rate. Besides, a variable cost should also be considered to cover the unexpected cost such as parts replacement. As mentioned earlier, variable cost also consists of the maintenance cost. Due to the ageing of equipments, it is expected a major maintenance would occur after a couple of years of operations. Therefore, escalation rate of 2% is applied in the variable cost. The relationship of aforementioned parameters is illustrated as in Fig. 16.

Financial planning is the crucial part of the project. From the estimated construction cost for a project to the analysis of the cash flow is very important to convince the decision maker to commence a project. For this research, it is assumed that the financial support from the government could be secured. From the total amount of RM 50 million, three wind turbines could be constructed based on the assumptions made. A 10% down payment is made and others will loan from the local banker. Although the financial support is purposely subsidising by Malaysia's government for the renewable energy development, the ROI of the same scenario is investigated. Therefore, the authorities could make the judgment on the investment whether is viable. The flow diagram of the cash flow analysis is clearly presented in Fig. 17.

The loan payment as indicated in the figure is the annual payment that needed to pay to the banker based on Eq. (3). Annual

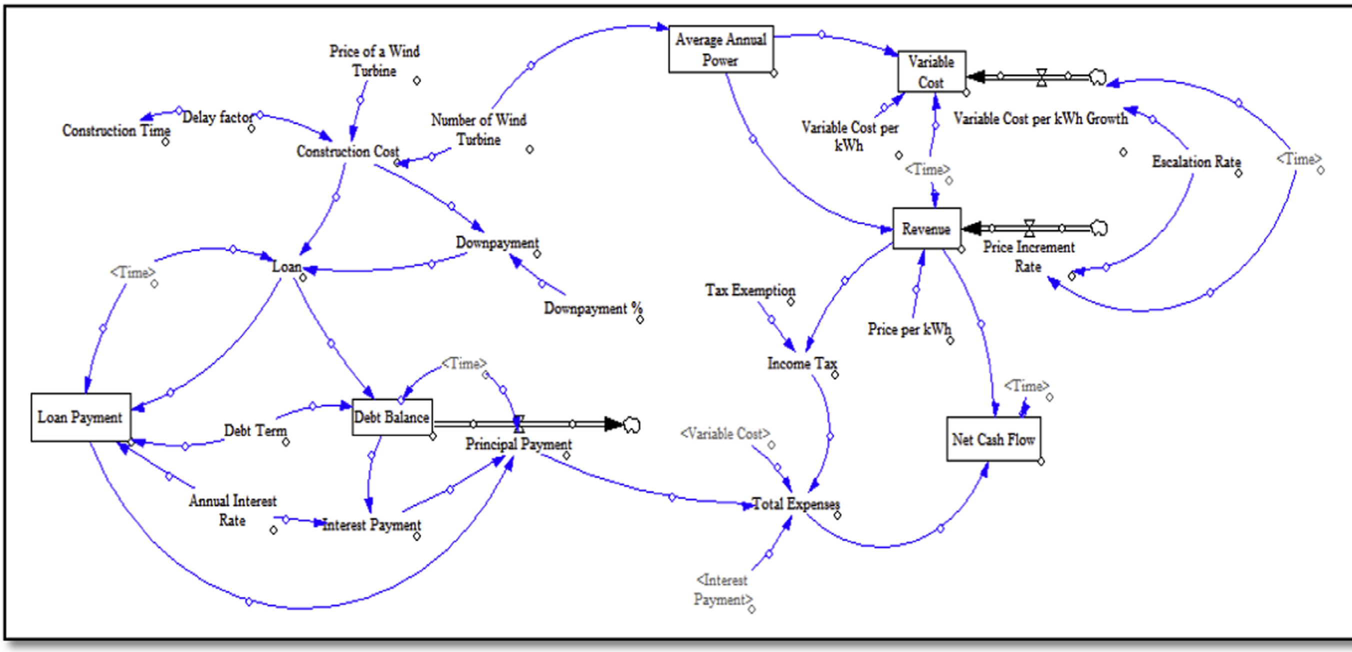

Fig. 17. Flow diagram of the financial planning for wind power project in Malaysia.
Source: Author's construction based on VENSIM software.

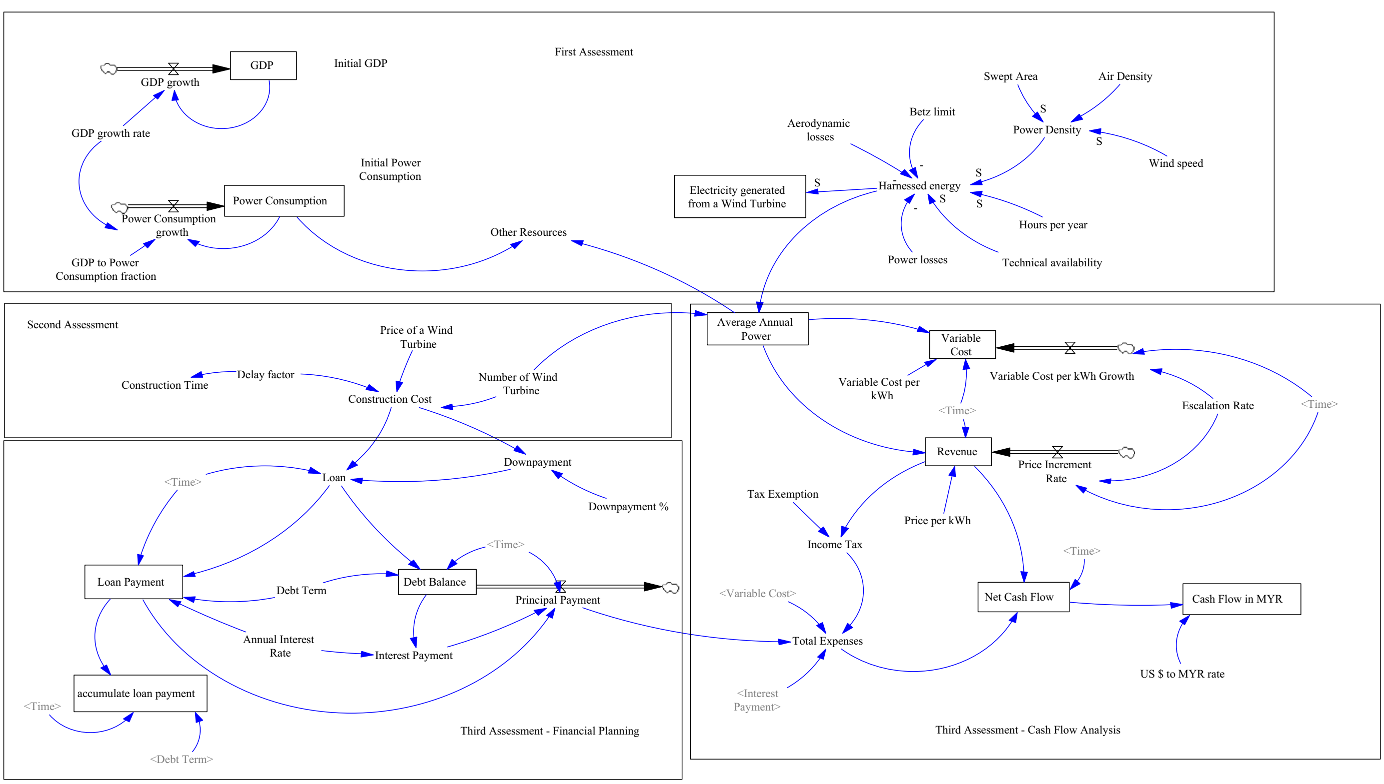

Fig. 18. The overall flow diagram of the wind power project in Malaysia.
Source: Author's construction based on VENSIM software.

loan payment consists of the interest payment and principal loan payment. Banker would charge the interest payment accordingly based on the agreed interest rate. A debt balance is the deduction of the principal payment from the total loan amount. The effective interest payment is based on the total amount in a loan account. The interest payment is directly proportional to the debt balance.

In order to calculate the cash flow, the total expenses and expected revenue should be obtained. In this part, the tax policy from the government is the manipulator of the amount. Since Malaysia's government offered 10 years tax exemption for the pioneer of renewable energy developer, hence, there will no extra charges on the total expenses. Therefore, a net cash flow with corresponding to the repayment period could be justified based on the positive cash flow from the result.

Due to the result is interrelated from the first assessment until the third assessment; the overall flow diagram from each

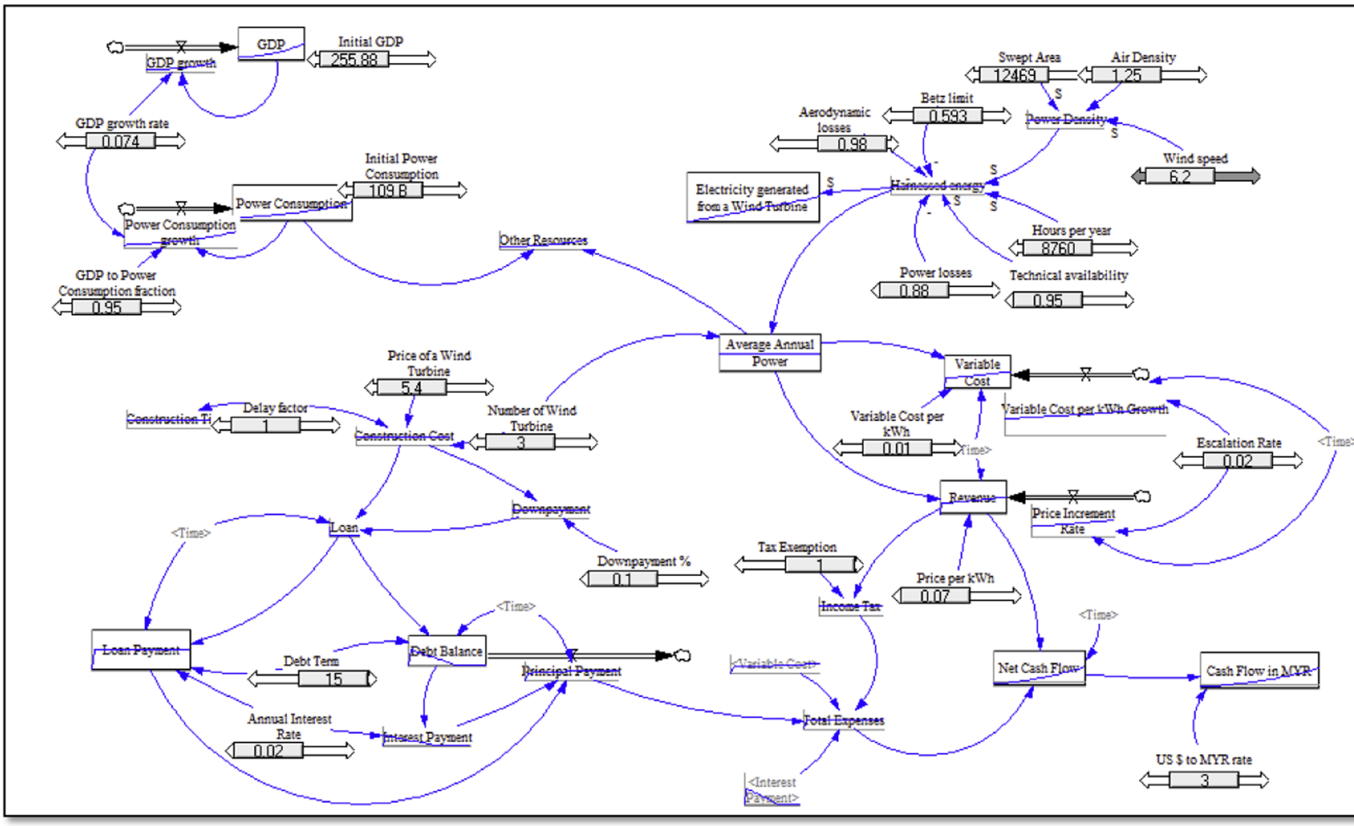

Fig. 19. Overall system dynamics analysis on wind power project in Malaysia.
Source: Author's construction based on VENSIM software.

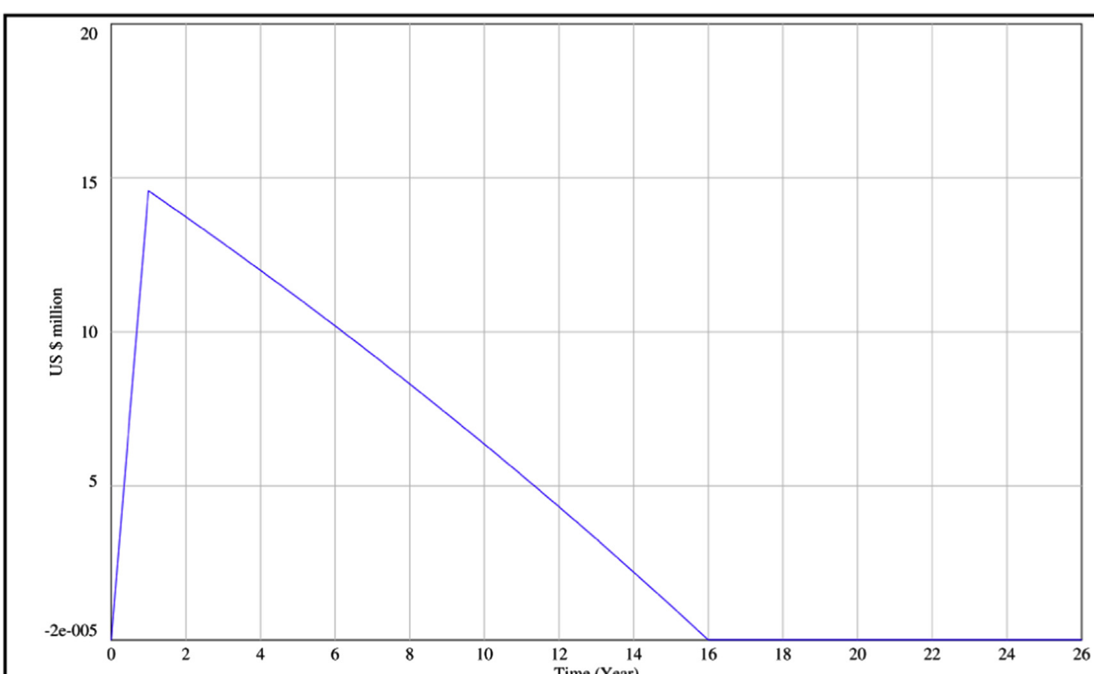

Fig. 20. The debt balance in the loan account.
Source: Author's construction based on VENSIM software.

assessment is combined as shown in Fig. 18. The system dynamics simulation by using the Vensim analysis tool is shown in Fig. 19. As in the figure, the constant values entered in the system could be adjusted depending on the site specifications and assumptions made.

The debt balance analysis is shown in Fig. 20. With a debt term of 15 years, the debt settlement will be at the 16th year as the loan payment is started from the first year of wind turbines' operation. Therefore, a steep curve is observed in the figure. Meanwhile, the

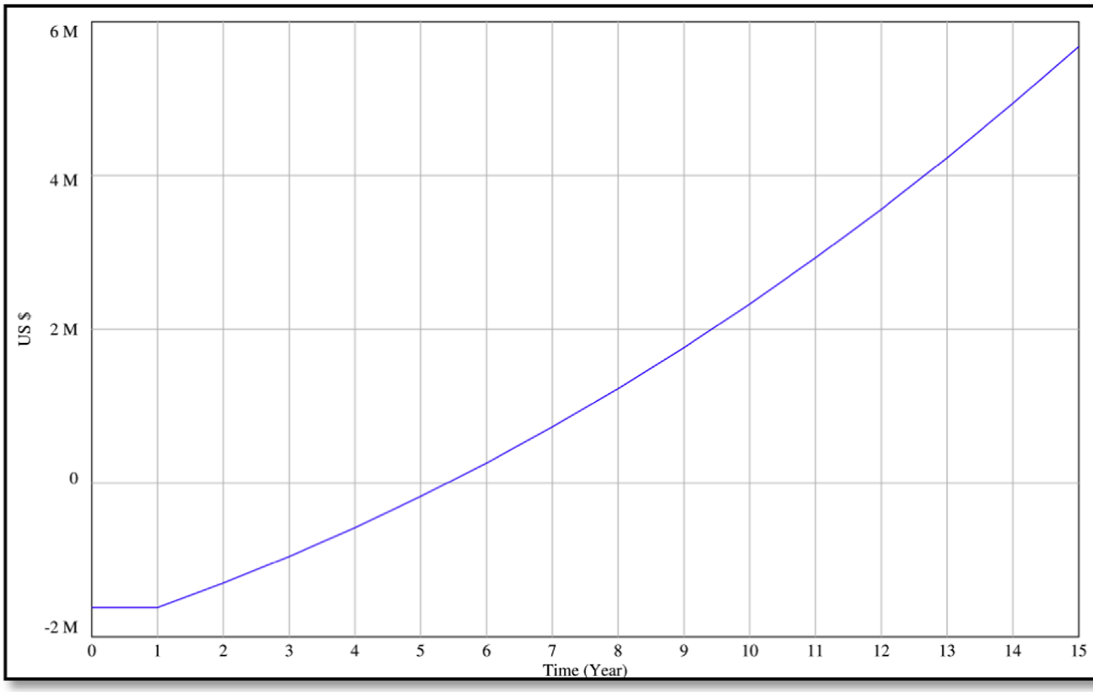

Fig. 21. The net cash flow of the wind power project in US $.
Source: Author's construction based on VENSIM software.

Table 3
Assumption of the wind power project.

Financial	
Down payment (%)	0.1
Interest rate (%/year)	0.02
Debt term (years)	15
Site	
Average wind speed (m/s)	6.2
Average annual output (kW h/wind turbine)	7904,500
Average cost of electricity ($/kW h)	0.071
Electricity escalation rate (%/year)	0.02
System cost	
Total installed cost ($/wind turbine)	5400,000
Variable cost ($/kW h)	0.01
Variable cost escalation (%/year)	0.02

ROI period can be observed from Fig. 21. At the point of intersection of the graph with the value "0" in the *y*-axis, the invested cash flow is changed to positive value. This indicates the breakeven point of the investment.

There are some assumptions made for this research. The assumptions of the analysis are tabulated in Table 3.

5. Discussion

For this paper, system dynamics analysis is being used for the case study of the wind power project in Malaysia. The stock flow diagram and CLD are used in the analysis. CLD is more efficient in giving the draft concept of the system. However, the stock flow diagram is preferred for the accurate analysis. The wind power project analysis is divided into three major parts. Each part is analysed by using system dynamics approach. After a sectional analysis was completed, it was then combined with each other as a whole system analysis. For the first assessment regarding the electricity generation, some hypotheses were made.

Hypothesis 1. Wind speed and swept area are directly proportional to the electricity generation of a wind turbine.

Hypothesis 2. GDP growth is proportional to the power consumption of a nation.

In order to prove Hypothesis 1, the wind speed is manipulated from 6 ms^{-1} to 8 ms^{-1}. The graph of the respective wind speed corresponding to the average annual power is shown in Fig. 22. The average annual power shown is the estimation of power generation from three identical wind turbines. As wind speed increase, the power generated is also increased with the power of 3. This result has proven the Hypothesis 1 is correct.

On the other hand, the Hypothesis 2 is proven by the result as shown in Fig. 23. In the time frame of 25 years, the power consumption is increased proportionally to the GDP growth. This is reasonable as a high profit country will consume more electricity especially on the residents and industrial usage.

In the second assessment of the wind power project, it is highly related to the third assessment. A cash flow analysis of a project is relying on the financial management. However, an independent cash flow analysis without the interrelation between the systems does not give any significant result. Therefore, the overall system analysis as shown in Figs. 18 and 19 were constructed. From the results, the analysis of the net cash flow and the total expenses could compute. The summation of the total expenses and variable cost for 25 operational years is calculated by using system dynamics analysis tool in Fig. 24.

$$\text{Unit\_price} = \frac{\text{Total\_expenses}}{\text{Total\_power\_generation(kW h)}} \tag{5}$$

6. Conclusion

In conclusion, system dynamics can clearly state the causal relationship for the project development in wind power for

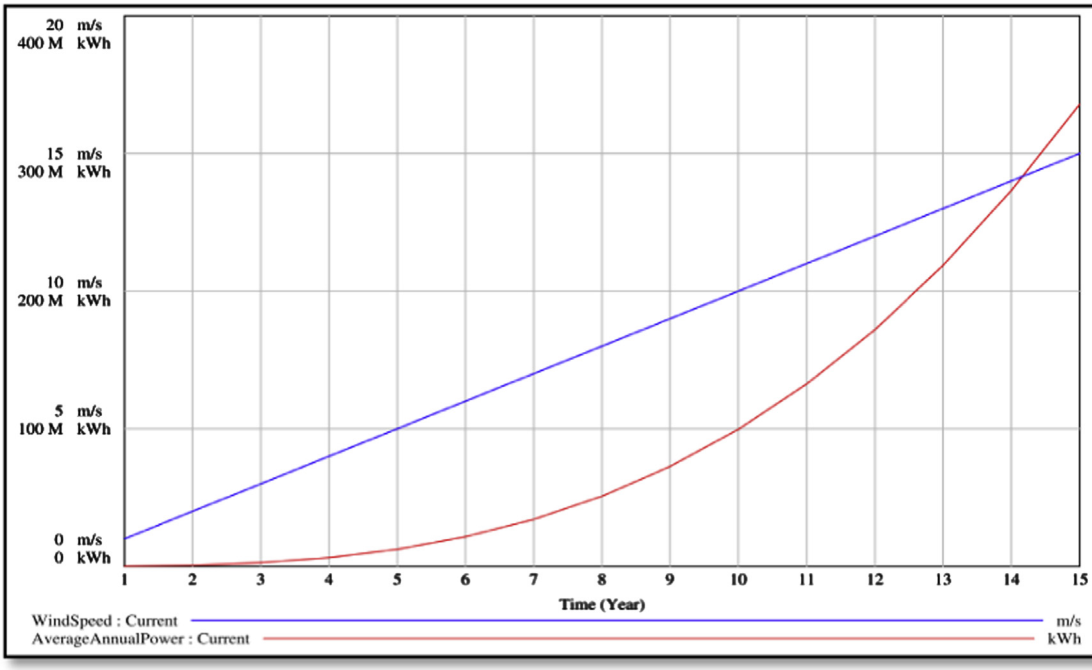

Fig. 22. The relationship in between wind speed and average annual power.
Source: Author's construction based on VENSIM software.

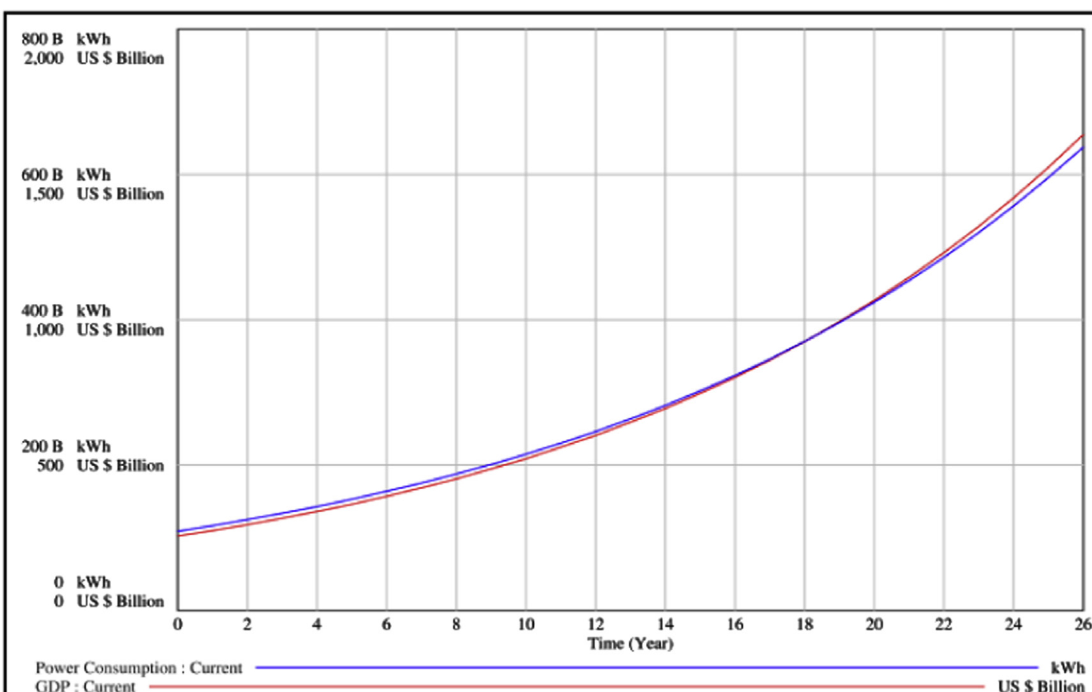

Fig. 23. The relationship in between GDP and power consumption.
Source: Author's construction based on VENSIM software.

Malaysia. Wind-power project is feasible in Malaysia as long as the project is well planned. The site survey and the wind speed prediction that can calculate the annual wind power generated is essential for the further analysis. For a new wind power user, the government's supports play the important role in development of wind power. Malaysia government is aiming to have 5374 GW h of renewable-energy generation for the year 2015. For the variety of renewable power generation, the wind power could be included. At the first stage of planning, the suggestions of experts from other wind power pioneer countries are necessary. Although the wind speed in Malaysia might be lower if compared with Denmark, China or United States, the modification of motor or the installation of booster in wind turbines can be done in order to adapt the environment in Malaysia. Renewable energy is not to reduce the carbon dioxide amount in the atmosphere, but it can reduce the emission of carbon dioxide to the atmosphere. The impacts of

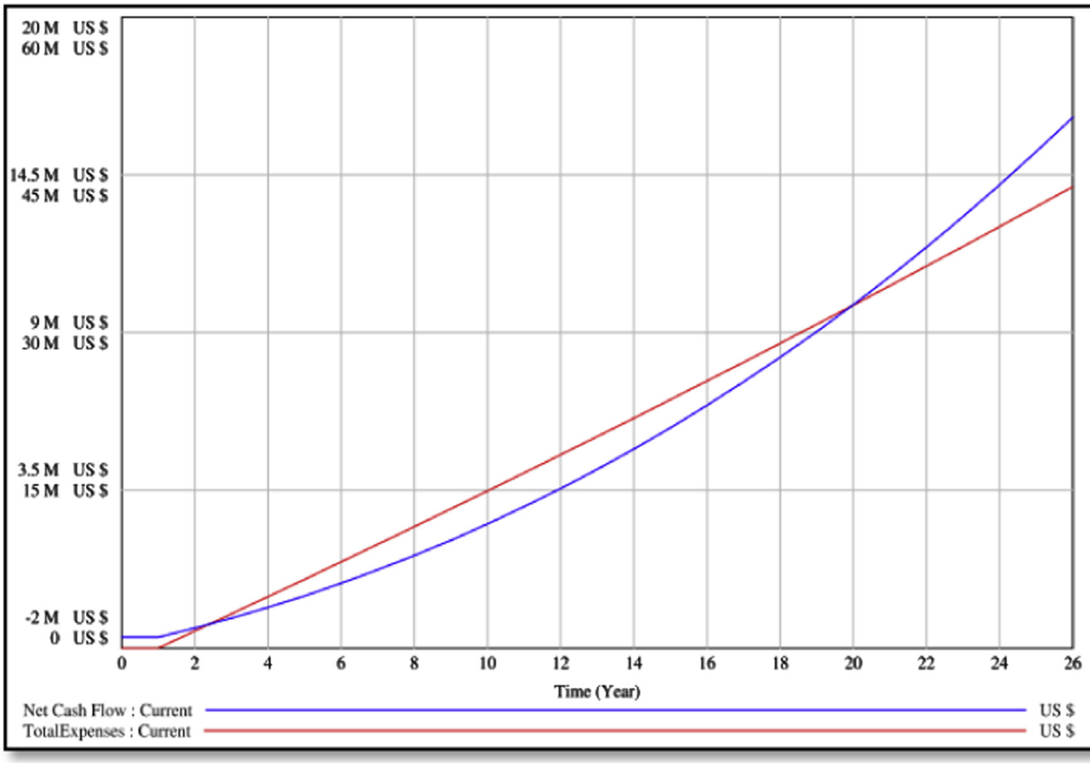

Fig. 24. Graph analysis for net cash flow and total expenses including variable costs.
Source: Author's construction based on VENSIM software.

saturated carbon dioxide in the atmosphere might cause a lot of serious problems. Hence, human being must have consensus that the reduction of carbon dioxide is the responsible of everyone, not just a country.

Acknowledgments

Authors would like to thank the Ministry of Higher Education Malaysia (MOHE) for giving the scholarship to the author in order to accomplish this research. Furthermore, the authors would like to thank Ministry of Energy, Green Technology and Water Malaysia (KeTTHA), Ministry of Higher Education, Malaysia (MOHE) and The Office for Research, Innovation, Commercialization, Consultancy Management (ORICC), UTHM for financially supporting this research under the Fundamental Research Grant Scheme (FRGS) grant no. 0905 in funding this research.

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